WOLSONG 3 FULL SCOPE SIMULATOR CONVERSION

• L3 MAPPS Inc. | Power Systems and Simulation

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Outline

• About L3Harris and our Power Systems and Simulation business
• Project Background
• Simulator Conversion Project
• Conclusions
L3 MAPPS INC., SUBSIDIARY OF L3HARRIS

World leader in automation and simulation
About Us

L3Harris Technologies (NYSE: LHX)
HQ: Melbourne, Florida, USA
50,000 employees
US$17 billion (2018)
4 Business Segments

INTEGRATED MISSION SYSTEMS
SPACE AND AIRBORNE SYSTEMS
COMMUNICATION SYSTEMS
AVIATION SYSTEMS

L3 MAPPS INC.
HQ: Montreal
3 Markets: Naval, Power Gen., Space Automation & Simulation

Global NPP Simulation Footprint
Our History

1973 - 2005

1973: Entered NPP simulation business - Pickering A (Canada)

2005 - 2019

2020: Global Leader in Nuclear Power Plant simulation
CANDU | PWR | BWR | GCR | MSR

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Power Systems and Simulation
Technologies and Services for Nuclear Know-how

Full Scope Operator Training
Simulators/Upgrades for RO and SRO Licensees

Technology-enabled Training Services Build-Own-Operate-Train

Newcomer and Classroom Training Technologies

Early Learning Technologies

Plant Lifecycle Support Technology
De-risking Plant Design → Field Worker Training → Decommissioning
Most Comprehensive Simulation Toolset in the World

Fully graphical NPP simulation suite
PROJECT BACKGROUND

Wolsong 3 Full Scope Simulator Conversion
Background

- Korea Hydro & Nuclear Power (KHNP), subsidiary of Korea Electric Power Corporation (KEPCO), provides about 30 percent of South Korea’s electricity supply
- Total installed capacity of more than 27,000 MW through the operation of
  - 17 nuclear power units in operation
  - 35 hydropower units
  - 16 pumped-storage power units
  - number of renewable energy facilities
- Wolsong Site in Gyeongju, North Gyeongsang Province
  - Four 700 MWe class CANDU reactors, Units 1 to 4
  - Unit 1 built first, Units 2-4 built in series

<table>
<thead>
<tr>
<th>Wolsong Site</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
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</thead>
<tbody>
<tr>
<td>Gross Output (MWe)</td>
<td>679</td>
<td>715</td>
<td>715</td>
<td>715</td>
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source: WNA and Global Energy Observatory
Background

• Contract awarded to build Wolsong 1 Full Scope Simulator in March 2016

• Work suspended in 2Q 2018 following election
  – Most work finished
  – Hardware and Software FATs completed
  – MCR panels delivered to site
  – Awaiting start of on-site acceptance testing

• Long process leads to contract amendment at end-4Q 2018
  – Convert Wolsong 1 Full Scope Simulator to Wolsong 3 Full Scope Simulator

• NSSC approves permanent closure of Wolsong 1 on 24 December 2019

• NSSC approves increased capacity for interim used fuel storage at Wolsong site on 10 January 2020
WOLSONG 1 → WOLSONG 3
FULL SCOPE SIMULATOR CONVERSION

Wolsong 3 Full Scope Simulator Conversion
Wolsong 3 Full Scope Simulator Conversion

• Repurpose Wolsong Unit 1 (W1) Full Scope Simulator (FSS) to become primary training simulator for Wolsong Unit 3 (W3)

• Two plant simulation baseline sources
  – Wolsong 1 FSS – nearly completed
  – Wolsong 2 FSS – modernization RFT 4Q 2008

• Extensive changes to the W1 FSS panels to make them specific to W3
  – W1 MCR Panels returned from South Korea to Canada for rework
  – Largest part of work
Wolsong 3 FSS Conversion – Scope Overview

• W1 FSS MCR panels reworked to accurately represent W3 MCR
• W1 FSS Computer and Peripherals repurposed
• Plant Models
  – Adjustments to W1, W2 simulation models already developed and validated
  – Addition of two simulated systems
• Severe Accident Simulation (SAS)
  – W1 FSS SAS to be carried over and updated to be W3-specific
  – 2D and 3D SAS graphics updated
• W1 FSS Virtual (Soft) Panels modified to be W3-specific
• Active Schematics
  – Majority of W1 FSS active schematics reused with minor modifications
  – Electrical distribution schematics redeveloped
• Digital Control Computers* (DCC) emulation for W3
• W2 FSS Mark V and AVR systems reworked to accurately represent W3

*DCC systems used to monitor and control all major reactor and power plant functions
Wolsong 3 FSS Conversion – Scope Overview

- W1 plant models (Reactor, PHT, Containment)
- W2 Plant models (BOP, Primary Aux, I&C, Electrics)
- W1 SAS & 2D/3D

Integrate Model Updates & Calibrate

- W1 Specific Panels
- W3-specific Plant Model

Acceptance Test

- Port Models
- H2 Monitoring D2O Supply
- Active Schematics Soft Panels DCC Emulation

Rehost to Orchid®
Main Control Room Panels

• Rebuild of W1 FSS MCR Panels to make W3-specific FSS (19 → 20 sections)
  – W1 cabinet housing retained
  – Panel modules 1000, 2000 & 3000 changed for W3 FSS
  – W1 FSS instruments and components reused wherever possible
  – W1 FSS components that cannot be reused catalogued and returned to KHNP with delivery of W3 FSS

• New Fire Protection Panel

• I/O system components (Beckhoff compact I/O and Power Supplies) repurposed from W1 FSS

• All cabling and wiring redone
Main Control Room Panels

- Main differences between W1 FSS and W3
  - Panel Modules 1000/2000/3000 → could not be salvaged
  - DCC (RAMTEK) Monitors → could not be salvaged
  - Annunciators → could not be salvaged
  - Micromod Controllers → completely different for W3
  - Switches → Approx. 20% salvaged; most switches have different positions
  - Meters → Approx. 70% salvaged with 90% of the scales changed
  - Pushbuttons → Approx. 200 additional pushbuttons added for W3
  - Panel Color & Texture → Very similar to W1
  - Miscellaneous → Blanking plates, wiring labels, escutcheon plates, gravoply/lamacoids, etc. to be redone
Computers and Peripherals, Software Platform

• W3 FSS C&P layout similar to W1 FSS
  – W1 FSS computer hardware and network equipment repurposed for W3 FSS
  – New PCs used for Mark-V HMI

• Commercial off-the-shelf software from W1 FSS reused for W3 FSS
  – Reinstallation from scratch

• Latest L3Harris Orchid® toolset for W3 FSS Conversion project
Plant Models

• Reactor and RCS models from W1 FSS
  – Already developed and thoroughly validated during W1 FSS FAT
  – Calandria (Reactor Core)
  – Steam Generators
  – Reactor Coolant System (Shutdown Cooling, Primary Heat Transport (PHT), Pressurizer)
  – Reactor Auxiliary Systems (Containment Isolation, Channel Temperature Monitoring)
  – Adapt for W3
  – Redo connections between the process systems and I&C
  – Recalibrate the PHT and reactor per W3 reference plant

• Remaining process models taken from W2 FSS
  – W3 much closer in design to W2 than to W1
  – Adapt models to match per W3 reference plant

• New Simulated Models (not part of W1 FSS)
  – Hydrogen Monitoring System
  – D2O Supply System
Severe Accident Simulation

• MAAP4-CANDU model from W1 → adapt for W3
  – Previously integrated and validated with Core and RCS
  – MAAP4-CANDU adapted to include W3 MAAP4 parameter file
  – Visualization graphics enhanced

• Systems replaced by MAAP4-CANDU during SAS
  – Containment & Reactor Vault
  – Calandria
  – PHT System
  – Steam Generators

• MAAP4-CANDU interfaces to Orchid® models
  – Emergency core cooling system (ECCS)
  – Shutdown cooling, feed and bleed
  – Moderator and end shield cooling
  – Dousing system,
  – Containment HVAC,
  – Feedwater, blowdown and main steam and I&C
Plant Computers, Instructor Station Graphics

Plant Computers

• Fire Detection System
  – New W3 FSS Panel 613
  – Simulated HMI and I&C model from W1 FSS used as-is for W3 FSS

• DCC Emulation
  – W1 FSS DCC-X emulation utilized for W3 FSS with specific changes for interfaces

• Mark V HMI and AVR
  – Taken from W2 FSS as-is

Instructor Station Graphics

• Virtual (Soft) Panels
  – Revamped W1 FSS soft panels to match W3

• Active Schematics
  – Reuse W1 FSS Active Schematics for W3 FSS
  – Minimal graphical modifications
  – Rename plant equipment to W3 naming convention
  – W3 Electrical Distribution different
  – Major changes to schematics to be W3 specific
Acceptance Testing

• Testing program shorter than typical FSS
  – Hardware FAT, Software FAT and SAT \( \rightarrow \) 14 weeks

• Hardware acceptance test for W1 FSS adapted for use on W3 FSS

• Performance ATPs
  – W2 FSS adapted for W3 FSS models acceptance testing
  – W1 FSS Severe Accident Simulation ATPs
  – Added specific ATPs for new H2 Monitoring & D2O Supply Systems
Current Status

- 3Q 2019: Factory Acceptance completed on W3 Panels Rebuild
- 4Q 2019: Simulator Software Factory Acceptance Complete
- 4Q 2019: W3 FSS shipped to Korea
- 1Q 2020: Simulator Installation
- 1Q 2020: On-site Acceptance \( \rightarrow \) W3 FSS Ready for Training
CONCLUSIONS

Wolsong 3 FSS Conversion
Conclusions

• KHNP and L3Harris changed a bad situation into a win-win project
• Leveraged work done on W1 FSS and W2 FSS, enabling quick development of W3 FSS
• Most of project team from W1 FSS redeployed for W3 FSS Conversion ensuring continuity
• L3Harris developed both the W1 FSS and the W3 FSS Conversion on time and on budget
• Our start in power plant simulation was on CANDU simulators (1973) → always fun to deploy another
Cernavodă Simulator Upgrade Recently Awarded

- Announced 3 December 2019
- Societatea Nationala Nuclearelectrica S.A. (SNN)
  - Romanian state-owned utilities company
- Stage 1
  - Upgrade simulation computers and operating systems; re-platform existing plant models to Orchid® simulation environment
  - Redevelop PHT, Boilers and Containment models Orchid® Modeling Environment
  - Enhance simulator to include severe accident simulation capabilities using MAAP5-CANDU*
    - With 2D and 3D animated, interactive visualizations of reactor vessel and containment building
  - Stage 2
    - Replace simulator’s AC and DC power supplies
    - Replace legacy Datapath SC I/O system with new compact I/O system (driven by Orchid® Input Output software)

*A valid license to MAAP5 from EPRI as well as the right to MAAP5-CANDU from the CANDU Owners Group (COG) is required prior to a customer being able to use MAAP5-CANDU with Licensee’s simulator products. EPRI and COG do not endorse any third-party products or services.